Statistical Analysis of Critical Socioeconomic Factors in the Development of COVID-19 Disease*

Sophia V. Ponomarenko
SophiGen inGr, Bönen, Germany

The study aimed to analyze the impact of several economic and social factors on the course of the COVID-19 pandemic by comparing statistical data in large and representative samples and to assess the critical factors influencing the development of the infectious process of the SARS-CoV-2 virus.

To create this review, the necessary publications were found on the Internet for the selected keywords both in one tag and different tag combinations. Statistics of economic and social factors were based on data available on the Internet. The Pearson correlation coefficient (r) to determine the statistical relationship was used.

The relationship between economic or social factors and the impact of the 15-month COVID-19 pandemic in different regions was investigated using various available statistics for five continents and 52 countries for the first time. A positive relationship between the consequences of viral epidemic and GDP per capita or the type of human diet was found with correlation coefficients in the range of 0.42–0.87. The development of the viral epidemic showed a less clear correlation with population density from r = -0.18 to r = -0.28, depending on the selected group of countries. For island nations, geographic isolation was the dominant defense against SARS-CoV-2 infection.

The comparison of the development of COVID-19 according to statistical data in different regions and the study of economic or social aspects, performed on large representative samples, showed that the productive infection and pathogenicity of SARS-CoV-2 increased with a high standard of living and excessive consumption of staple foods. In countries with low GDP and adequate protein or fat intake, the rates of SARS-CoV-2 infection, and death did not exceed the minimum epidemic threshold. The study of the influence of consumed macronutrients on the dynamics of the infectious cycle of the SARS-CoV-2 virus will help explain the reason for such resistance to the pathogen. Such a study would require further comparative analysis of COVID-19 pandemic statistics.

Keywords: coronavirus SARS-CoV-2, COVID-19 pandemic, diet, GDP, pathogenesis, risk factors, statistics.
JEL: A31, D31, P36, Y10.
doi: https://doi.org/10.34023/2313-6383-2023-30-1-90-100.

For citation: Ponomarenko S.V. Statistical Analysis of Critical Socioeconomic Factors in the Development of COVID-19 Disease. *Voprosy Statistiki*. 2023;30(1):90–100. (In English)

Статистический анализ критических социально-экономических факторов развития болезни COVID-19*

София Васильевна Пономаренко
ООО «SophiGen inGr», г. Бёнен, Германия

Цель исследования – на основе сопоставления статистических данных больших репрезентативных выборок проанализировать воздействие ряда социально-экономических факторов на течение пандемии COVID-19, а также оценить критические факторы, влияющие на развитие инфекционного процесса вируса SARS-CoV-2.

Для подготовки обзора источников по данной теме были найдены необходимые публикации в Интернете по выбранным ключевым словам – как по одному слову, так и по различным сочетаниям слов. Статистическая информация, характеризующая социальные-экономические факторы, была получена из баз данных, доступных в Интернете. Для определения статистической взаимосвязи использовался коэффициент корреляции Пирсона (r).

Впервые была исследована взаимосвязь между социально-экономическими факторами и последствиями 15-месячной пандемии COVID-19 в отдельных регионах с использованием различных доступных статистических данных для пяти континентов и 52 стран. Установлена положительная связь между исходом эпидемии вируса SARS-CoV-2 и ВВП на душу населения, а также типом питания человека с коэффициентами корреляции в диапазоне 0,42–0,87. Развитие вирусной пандемии показало менее четкую связь с плотностью населения (значения коэффициента r от -0,18 до -0,28 в зависимости от группы стран). Для островных государств географическая изоляция была доминирующей защитой от распространения инфекции SARS-CoV-2.

Сопоставление статистических данных о развитии COVID-19 в различных регионах и изучение как экономических, так и социальных аспектов, выполненное на больших репрезентативных выборках, показало, что продуктивная инфекция и пато-

* The author's style has been preserved.
Авторская стилистика сохранена.

генность вируса SARS-CoV-2 возрастали при высоком уровне жизни и чрезмерном потреблении основных продуктов питания. В странах с низким ВВП и адекватным потреблением белков или жиров показатели инфицирования SARS-CoV-2 и смертности не превышали минимальный эпидемический порог. Детальное изучение влияния потребляемых макроэлементов на динамику инфекционного цикла вируса SARS-CoV-2 даст возможность объяснить причину устойчивости к возбудителю. Для такого изучения потребуется дальнейший сравнительный анализ статистических данных о пандемии COVID-19.

Ключевые слова: коронавирус SARS-CoV-2, пандемия COVID-19, типы диеты, ВВП, патогенез, факторы риска, статистические данные.

JEL: A31, D31, P36, Y10.

doi: https://doi.org/10.34023/2313-6383-2023-30-1-90-100.

Для цитирования: Пономаренко С.В. Статистический анализ критических социально-экономических факторов развития болезни COVID-19. Вопросы статистики. 2023;30(1):90–100. (На английском языке)

Introduction

A virus pandemic is an epidemic of an infectious disease that affects a huge number of people in a lot of countries or worldwide[1]. The discovered 2019 pathogenic Coronavirus SARS-CoV-2 caused the disease that alarmed the human community. The contagious grave disease was officially named COVID-19 by WHO and the pandemic of the highly transmissible aerosol-generated particles disease was recognized on 11 March 2020[2]. Conclusions about the development of each epidemic are based on statistical data of an infection spreading in the population during the termed period. Using these statistical data, models of the new epidemic process were assembled and a strategy to combat the pathogenic infection was developed [1–3].

Epidemiologists, virologists, and clinicians analyze the risks of a pandemic and their factors using statistical data. The results of intensive studies of the structure and function of the SARS-CoV-2 virus [4–6] as well as risk factors for COVID-19 disease expansion, carried out over the past two years by researchers from the world community [7–13]. A huge number of results and conclusions concerning the pandemic have been published on the Internet and statistical analysis should help in realizing methods to stop virus SARS-CoV-2 infection.

The COVID-19 pandemic is a global burden process with medical, social, and economic components. Unfortunately, even experts cannot give an exact date for the end of the current pandemic. There is still no effective etiotropic drug against COVID-19. The main conclusion from numerous studies was that severe disease progression and high mortality were observed in the elderly and patients with serious comorbidities. Also, the dependence of the rate of development of the epidemic process on the living area [10] and population density in some countries [11–16] was studied. In the USA and UK, the severity of COVID-19 pathogenesis in different ethnic groups was compared [8, 13, 14, 16, 17]. The impact of the economic situation on COVID-19 disease outcomes has been studied in some countries [7, 10, 18]. However, these data on the relationship between socioeconomic statistical data and the COVID-19 pathogenesis values, obtained in discrete countries and several patient groups, sometimes contradict each other. Socioeconomic conditions determine the type of diet in the regions.

Some countries could not provide the real COVID-19 statistics. For a more representative statistical analysis and comparison of the influence of several economic and social factors on the outcome of COVID-19, it is necessary to analyze data for the large samples. This review firstly analyzes the impact of different socioeconomic and dietary factors on the rate of prevalence (RPr), infection fatality rate (IFR), and case fatality rate (CFR) on five continents (continental regions) and in 15 country groups throughout 15 months. Understanding the role of factors reducing the epidemic progress should assist in creating an adequate model of pathogenesis to find an approaching treatment to overcome the COVID-19 pandemic.

Materials and methods

For the review, the required information was systematically searched on the Internet using preferred keywords, which were managed as unique tags or in their various arrangements. Statistical population groups were formed from a lot of data. Most of the statistics were acquired from the following well-

[1] WHO. Coronavirus Disease (COVID-19) Pandemic. URL: https://www.who.int/health-topics/coronavirus (accessed 10.09.2021).
[2] Ibid; CDC. COVID-19. URL: https://www.cdc.gov/coronavirus/2019-ncov/index.html (accessed 10.09.2021).

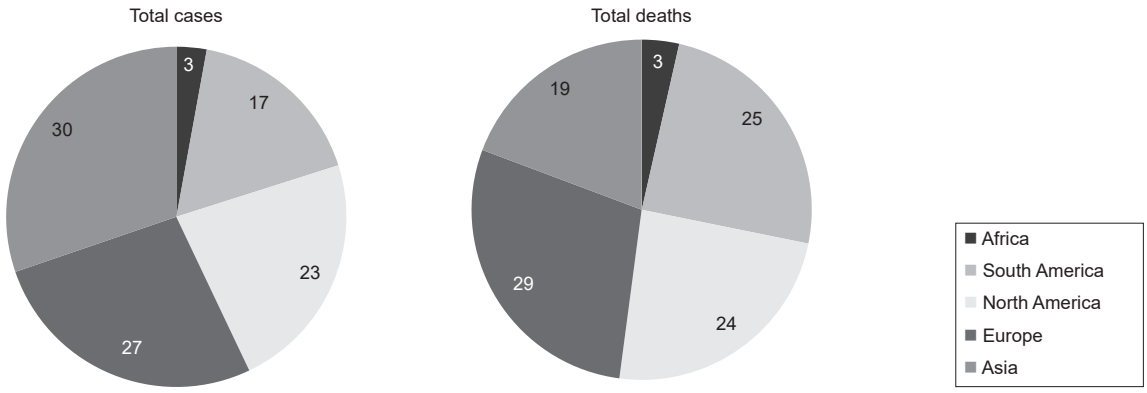
known and reliable databanks: https://www.who.int; https://www.worldometers.info; http://www.fao.org; https://ourworldindata.org; https://databank.worldbank.org; https://www.imf.org. The rate of prevalence or infection fatality rate of the virus was calculated as a ratio between the number of total cases and population. Case fatality rate is the ratio between total COVID-19 deaths and total registered infection cases in percent. The relationship between statistical data was estimated as a Pearson correlation coefficient (r).

Results and discussion

1. Epidemiological situation with Coronavirus SARS-CoV-2 on different continents. The virus SARS-CoV-2 causes human severe acute respiratory syndrome (SARS) [1, 3, 7, 8, 19, 20]. The affected infection disease COVID-19 can occur in an asymptomatic, acute mild, or severe respiratory form. The most common complication of COVID-19 is pneumonia, which can lead to SARS and destructing of the lungs in a short time. This very dangerous infectious disease triggers the deadliest clinical manifestations. The virus could infect several different human organs, causing septic shock and multiple organ failure, thrombosis, or embolism [19, 20]. A destructive feature of the disease is severe complications like post-COVID syndrome, which can continue for more than a year [19–22].

From 11 March 2020, when the global COVID-19 pandemic was declared, many infected persons have been identified in all countries and their global amount reached 175.6 mln on 10 June 2021, in total 90.8% of them were recovered. About four million people died from COVID-19 on this date due to the syndrome disorder[3]. All epidemiological data used in the review were from the study period of 11 March 2020 – 10 June 2021. Analysis of statistical data from the continually rising of RPr and IFR through 15 months global pandemic gave practical lessons and epidemiological knowledge needed to combat the pathogen SARS-CoV-2 virus.

About half of the infected patients were from Europe and North America (NA) (Fig. 1).



Note. Fig.1 and Fig. 2 exclude information on Oceania due to scarce epidemiological data.

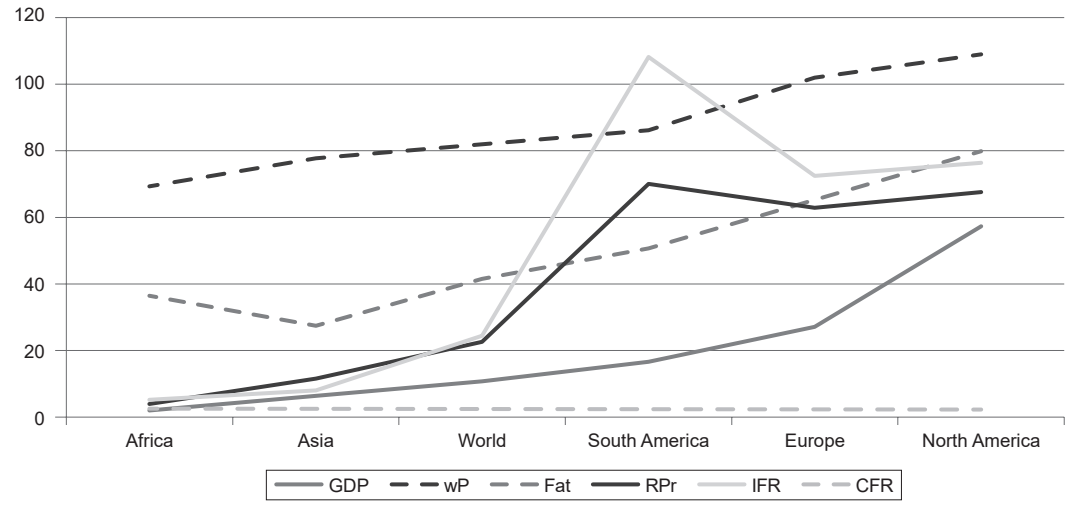
Fig. 1. **Distribution of infected or dead patients by different continents** (in percentages)

Source: Worldometer (accessed 10.06.2021).

The largest number of total cases was registered in the USA, India, and Brazil. Together in these three countries were detected more than 80 million infected patients, comprising more than 45% of globally affected people. On average, 2.25% of the global population was infected by the SARS-CoV-2 virus, but in some European countries, above 15% of the residents were infected by this pathogen. The highest incidence rate of the SARS-CoV-2 virus could exceed 80% in separate areas, where people were together in close contact with each other, while high humidity contributed to more efficient transmission of the pathogen.

Globally, the average mortality from COVID-19 was below 0.05%, but 2.27% of infected patients died[4]. The IFR was the lowest in Asia and Africa, it matches the RPr with a correlation coefficient r = 0.97 (Fig. 2, Table 1).

[3] Worldometer. URL: https://www.worldometers.info/coronavirus (accessed 31.05.2022).
[4] Ibid.



Note. Correlation between the RPr, IFR or CFR of the SARS-CoV-2 infection and GDP, amount of consumed whole protein (wP) or fat (Fat). Along the *y*-axis are given the values of the factors GDP, wP, Fat, RPr, IFR and CFR respectively: GDP (nominal) in US$ thousand/year/capita; wP = g/day/person; Fat = g/2/day/person; RPr = total amount infected / 1000 people (10.06.2021); IFR = total amount COVID-19 deaths / 50 000 patients (10.06.2021); CFR in %.

Fig. 2. **Relation between outcomes of the COVID-19 pandemic and socioeconomic factors on five continents**

Table 1

Correlation coefficients (r) between COVID-19 outcomes and different factors on five continents*

Factor	GDP	wP	RPr	IFR	CFR
GDP					0.06
wP	0.93				0.03
RPr	0.75	*0.84*			0.44
IFR	0.60	*0.69*	0.97		0.59
Fat	0.94	0.94	0.84	*0.71*	0.30

* Calculation was done for data from Fig. 2.

Both IFR and RPr of the SARS-CoV-2 virus varied significantly across regions and countries. For instance, IFR in Peru or Mexico was above 9%, while in the USA it was 1.79%, and in Iceland 0.45%[5]. More than half of the world's pandemic deaths have been confirmed in NA and Europe, where the populations have incomes several times higher than the world average[6]. The proportion of COVID-19 mortality among the population in NA was 0.15%, which was 15 times higher than in Africa (0.01%)[7]. Due to such enormously incomparable differences in statistical data, in some publications was suggested that methods of recording and documenting the confirmed cases might differ in several countries or that not all organizations provide real epidemiological facts [12, 23]. Large samples of statistical data are more representative, for example, information from continents or clusters of countries (Fig. 1, 2; Table 2).

Table 2

Regions of different countries from five continents

Region	Country
East Part of West Africa	Benin
	Niger
	Nigeria
termed	***BNN***
North Nile Region	Egypt
	Ethiopia
	Sudan
termed	***ESE***
Southern Africa	Botswana
	Namibia
	South Africa
termed	***BNS***
Southern Asia	Bangladesh
	India
	Nepal
	Pakistan
termed	***BINP***
Mainland South-Eastern Asia	Cambodia
	Laos
	Thailand
	Vietnam
termed	***CLTV***
Maritimeland South-Eastern Asia	Malaysia
	Indonesia
	Philippines
termed	***MIP***
Central Asia	Kyrgyzstan
	Uzbekistan
	Tajikistan
termed	***KUT***

[5] Worldometer (accessed 31.05.2022).

[6] Our World in Data. URL: https://ourworldindata.org (accessed 20.07.2021); World Bank Open Data. URL: https://data.worldbank.org/ (accessed 20.07.2021).

[7] Worldometer (accessed 31.05.2022).

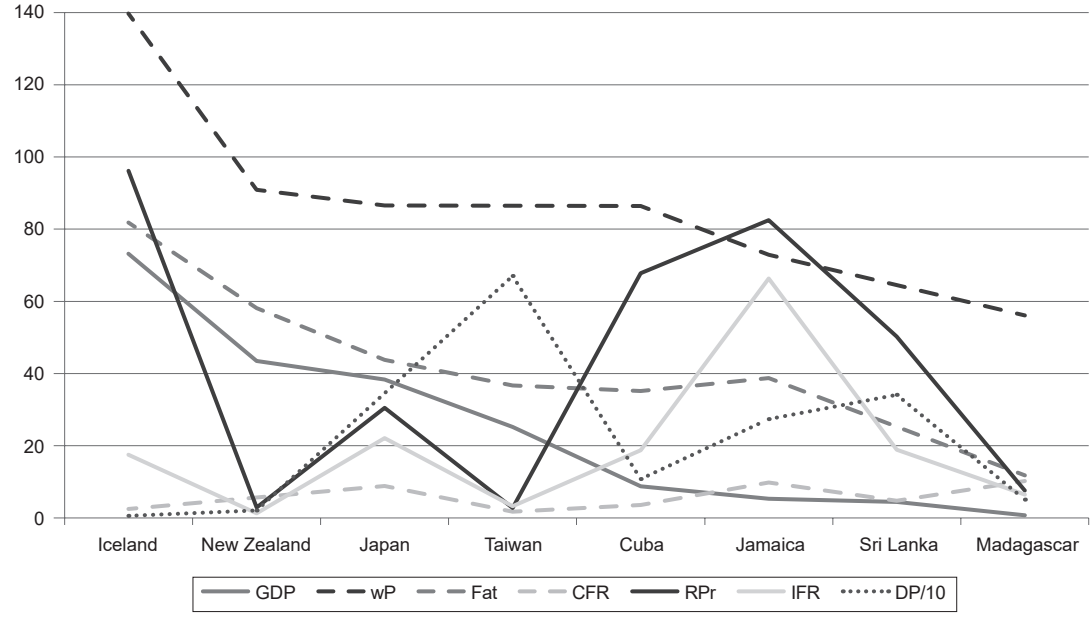
Ending of Table 2

Region	Country
Central Europe	Czechia
	Poland
	Slovakia
termed	***CPS***
Mediterranean Europe	Spain
	Italy
	Portugal
termed	***SIP***
Eastern Europe	Russia
	Ukraine
	Belarus
termed	***RUB***
Western Europe	Austria
	Belgium
	France
	Netherlands
	Switzerland
	Germany
termed	***WE***
North-West of South America	Bolivia
	Brazil
	Paraquay
termed	***BBP***
South-East of South America	Colombia
	Ecuador
	Peru
termed	***CEP***
Noth America	USA
termed	***NA***

On average in the world, roughly 22 persons out of a thousand were infected with the virus SARS-CoV-2[8], with the highest prevalence ratio in Europe (6.3%) or NA (6.8%) and the lowest in Africa or Asia, where the proportion of the infected patients was 0.38% and 1.1%, respectively. It disagrees with study in OpenSAFELY which considers, that Black and Southern Asian people were at higher SARS-CoV-2 risk compared with people of white ethnicity [13, 16].

2. SARS-CoV-2 epidemic development in island countries. A high level of social communication attributes in medical epidemiology to the main risk of a pandemic rising of airborne infections. Analyzing the development of the epidemic process in populations in which it is easy to achieve control of contacts with other countries, should allow for estimating the importance of physical isolation for speed and area of virus transmission.

The single island countries (sICs) group contains eight lands according to the following principle: the territory is located on one main island without land borders, with a population of more than 1 mln. There were two exceptions to this group: Japan is an archipelago and Iceland has less than 1 million citizens. Iceland is the only island representing Europe here. These eight sICs are located in various geographic and climatic zones of the Earth, and also significantly differ in population ethnicity, density, type of diet, and the level of GDP. It should be noted that the data in the group were highly heterogeneous across the categories. Nevertheless, the RPr of SARS-CoV-2 infection in each country was much or even many times lower than the world or continent average (Fig. 3).



Note. Correlation between RPr, IFR or CFR of the SARS-CoV-2 infection and GDP, amount of consumed wP or Fat and density of population (DP/10). Along the *y*-axis are given the values of the factors: GDP (nominal) in thousand US$/year/capita; wP = g/day/person; Fat = g/2/day/person; RPr = amount infected / 50 thousand people (10.06.2021); IFR = deaths / 200 thousand patients (10.06.2021); CFR = in %; DP/10 = people/sq km/10.

Fig. 3. **Relation between COVID-19 pandemic outcomes and socioeconomic factors in single island countries**

[8] Worldometer (accessed 31.05.2022).

The rates of the incidence and mortality in these sICs did not show a clear relationship between population density and GDP. At the same time, the level of protein or fat consumption in these countries depended on the GDP with a coefficient correlation of about 0.9 (Table 3), like in the rest of the world.

Table 3

Correlation coefficients (r) between COVID-19 outcomes in single island countries and different factors*

Factor	GDP	wP	Fat	RPr	IFR	DP/10
CFR	-0.45	-0.58	-0.47	-0.08	0.48	-0.18
IFR	-0.27	-0.11	-0.14	0.66		0.05
RPr	0.18	*0.48*	*0.42*			-0.28
Fat	0.88	0.89				
wP	0.91					

* Calculation was done for data from Fig. 3.

The RPr of COVID-19 in sICs related to protein and fat intake with r = 0.48 and r = 0.42, respectively. The IFR did not correlate with GDP or diet factors. In these island states, the RPr was an average of 0.56%, which was four times lower than the average in the world, which confirms the high efficiency of social isolation as a protective measure of the population against infection. However, mortality from COVID-19 could be higher in some sICs than the global average.

Implementation of a complex control of travel contacts with the help of administrative and medical-sanitary arrangements prevented the introduction and spreading of Coronavirus in these island countries and in Australia[9]. The WHO experts attributed high communication skills as one of the main risk factors for the Coronavirus and therefore recommended, first of all, restricting social contacts to prevent and combat the current COVID-19 pandemic.

3. Quantitative evaluation of socioeconomic factors and progress of virus infection. Different categories of risks prompting of SARS-CoV-2 infection process or aggravating the course of the disease were generally analyzed by WHO and other experts [7–18]. In the A.X. Tan and coworker`s publication [18] was suggested that income disproportion in the USA was associated with the rate of infection cases and COVID-19 deaths. Recently was unpredictably found high mortality rates for well-situated COVID-19 patients [9, 15]. The same tendency for GDP was found in statistical populations of continents with r = 0.75 for RPr and r = 0.60 for IFR (Table 1).

It is generally accepted that a correct diet regulates accurate body growth and building, also provides proper metabolism reactions and enhances the body's defense mechanisms [24]. Healthy nutrition is very important and anyway mistaken or unbalanced diet can be a risk factor affecting the development of virus pathogenesis[10]. Several research groups have shown that malnutrition or obesity exacerbated COVID-19 disease [9, 25–29]. Therefore, to increase immunity in case of SARS-CoV-2 infection, an optimal diet was recommended with the inclusion of all the necessary nutritional components, trace elements, and vitamins [25, 29–31].

Fig. 2 compares the numbers of total infected patients per one thousand or deaths per 50 thousand of the continent population. These numbers were very high for NA and Europe continents which included states with populations owning greater income. As was written above, in some countries was found an association between GDP and COVID-19 death rates [7, 9, 18]. Low COVID-19 burden was monitored in Africa and Asia, the numbers of recorded cases were roughly 20 and 6 times lower than in NA[11]. The heights of CFR (Fig. 2) were near in NA and Europe (2.26% and 2.30%), which were lower than in Africa (2.66%). If the COVID-19 prevalence and death rate correlate with GDP [9, 15], therefore it is vital to find an answer to the question: which component of wealthy being is the risk factor for the SARS-CoV-2 infection process? In some investigations was observed a relationship between COVID-19-associated infection or death rates and type of diet [25–37]. In those investigations was concluded that diet can be a factor among others affecting SARS-CoV-2 pathogenesis.

There is a correlation between GDP and the amount of protein or fat in human food in numerous nations and on different continents (Fig. 2–4; Tables 1, 3, 4). People with high GDP consume more fat and whole protein as recommended by WHO obligatory demand. There are a lot of countries in Africa or Asia with large populations consuming considerably less protein or fat as recommended by WHO [24]. The daily intake should be 1.2–0.8 g protein or fat per kg of person per day. In some nations in NA or Europe for many

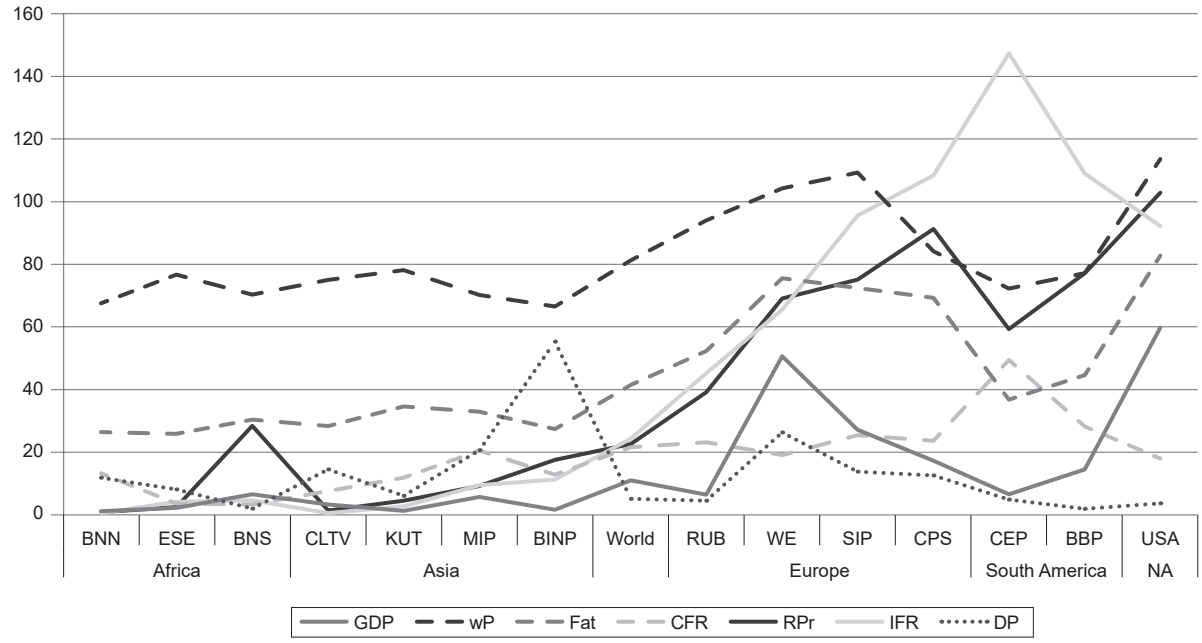
[9] Worldometer (accessed 31.05.2022).
[10] Eating Healthy Before, During and After COVID-19. URL: http://www.fao.org/fao-stories/article/en/c/1392499/ (accessed 20.07.2021).
[11] Worldometer (accessed 31.05.2022).

decades men eat nearly twice more protein or fat as recommended by WHO [24]. People need an adequate amount of total protein, carbohydrates, or lipids with an optimal ratio of animal and plant origin, as an example was recommended the Mediterranean diet [33, 37]. In Africa, the human diet contains the lowest portion of protein or fat in the world[12]. Fig. 2 shows the difference between continents in daily protein or fat intake per capita and outcomes of SARS-CoV-2 infection with tendency: less food protein composed with less fat – rarely infection incidences or IFR (with r = 0.84 and r = 0.69 for protein or r = 0.84 and r = 0.71 for fat). These correlation coefficients for continents were significantly higher than for sICs (Fig. 2, 3; Tables 1, 3).

4. Statistics of socioeconomic factors and outcomes of virus epidemic in different regions of five continents. More than a few scientific groups have investigated the effects of diet on COVID-19 disease progression and mortality in distinct nations [25–37]. These publications did not compare regions highly distinguished in COVID-19 consequences also a correlation between the amount of protein or fat intake and the gravity of SARS-CoV-2 infection after the fourth pandemic wave was not discussed. For the task of review, several countries of each continent were combined into 14 groups representing regions of different continents (Table 2). These groups were composed of a few neighboring countries with populations similar in ethnicities, habits, traditions, and eating preferences.

Some intracontinental COVID-19 data from group means of RPr or IFR were truly lower but others radically higher than the continental average. It means that the epidemic outcomes differ significantly between these 14 regions (Fig. 4).

Diversity in the amount of total protein and fat consumption concerning the 14 regions was also very high. The RPr and IFR had fewer variables within these groups than between them (Fig. 4; Table 4).



Note. Correlation between RPr, IFR or CFR of the SARS-CoV-2 infection and GDP or DP, amount of consumed wP or Fat. Along the *y*-axis are given the values of the factors: RPr = total amount infected / 1000 people; IFR = total amount deaths / 20 000 COVID-19 patients; CFR = in %, wP = protein g/day/person; Fat = g/2/day/person; GDP (nominal) in thousand US$/year/capita, DP = people/sq km/2.

Fig. 4. **Relation between pandemic outcomes of COVID-19 and socioeconomic factors in 14 regions of five continents**

Comparing epidemic statistics in regions with high and low rates should help assess risk factors for the pandemic. For that was particularly interesting to compare the states with epidemic rates more undersized than an ordinary continental. These are RUB in Europe, KUT, and CLTV in Asia, and BNN and ESE in Africa. Opposite to them the other regions: CPS in Europe, BNS in Africa, and the USA have higher RPr and IFR than corresponding continents. New mutants and more infection waves than

[12] Our World in Data (accessed 20.07.2021).

Table 4

Correlation coefficients (r) between COVID-19 outcomes in 14 regions and different factors*

Factor	CFR	RPr	IFR
RPr	0.53		
IFR	0.83	0.88	
wP	0.16	*0.69*	*0.45*
Fat	0.31	*0.87*	*0.63*
DP	-0.16	-0.18	-0.24
GDP	0.15	*0.76*	0.48

* Calculation was done for data from Fig. 4.

at neighbors could explain the highest values of RPr and IFR in the USA or CPS regions and statistical outlier for South America (Fig. 4). People from three states included in the 14 groups: Austria, France, and the USA consume the highest amount of protein 108–113 g and fat 159–166 g per day per person and comprise correspondingly RPr 72–103 [21] and IFR 1.2–1.8 per one thousand population, which are greater than average ones in all continents.

Populations in the RUB region eat less whole protein or fat than Western Europe showing lower RPr = 39 and IFR = 0.9 per one thousand people, compared with Europe`s mean RPr = 63 and IFR = 1.4. Ingesting of fat in Asia is less and in NA twice more than WHO recommended[13] [24]. Overconsuming of protein in the USA is more than twofold higher than in Asia. The consequences of the epidemic in Asia were less dramatic than in NA with contrary rates of RPr = 11.4 or RPr = 67.7 and IFR = 0.16 or IFR = 1.53 (Fig. 2).

The region of South-Eastern Asia has shown the world minimal amounts of infection and mortality cases per population. The rates in Laos or Vietnam of group CLTV were minimal, such as RPr 0.27 or 0.10 per thousand[14] and IFR 0.4 or 0.6 per million people (Fig. 4). These communities have low GDP and consume meals with 90 g protein/day/person in Vietnam or 83 g protein/day/person in Laos, which are higher than recommended by WHO. Societies in these two states consume fat: in Laos 49 and Vietnam 79 g/day/person. However, in the CLTV region, the incidence rates and mortality from COVID-19 were absolutely minimal. People here consume more protein than in other regions of South Asia or South-Eastern Asia, where the RPr was significantly higher. A feature of the territorial diet in the CLTV region is the highest consumption of soybean products. The world average consumption of soy protein is 0.77 g per day per person[15]. The main consumers of soybeans are residents of China, Southern, and South-Eastern Asia. One consumer in Vietnam ingests an average of 9.14 g of soy protein per day[16]. In Japan and Taiwan, the intake of soy products is almost an order of magnitude higher than the world median: 8.23 and 8.70 g of protein per capita per day[17]. The three nations: Vietnam, Taiwan, and Japan with the greatest soy supply per capita have largely higher than mean Asian population density (314, 673, and 347 people/sq km[18]). Their RPr and IFR were much lower than in neighboring states. It was uncertain relation between population density and outcomes of COVID-19 in 52 states (Fig. 4; Table 4).

African nations generally eat much fewer soy products than Asian[19]. In African regions BNN and ESE, the consumption of total protein or fat was lower than the world average, and at the same time, the RPr was an order of magnitude lower. In the Western Africa region, BNN was COVID-19 weaker than in other territories of Africa with RPr = 0.55 and IFR = 0.01 (Fig. 4). Average consumption was 67 g protein/day/person and 53 g fat/day/person in the BNN group.

The CFR should be associated with the level of medical care, it depends on IFR more efficiently than on GDP (Fig. 2, 4; Tables 1, 4.). Africa and Asia have very low epidemic data with the intake of whole protein in the range of 67–78 g/day/capita and fat 53-73 g/day/capita (Fig. 2.). Easy-going outcomes of COVID-19 (Fig. 4) were in regions with low GDP and consumption of protein or fat in the amount near or less recommended by the WHO.

The negative impact of excessive dietary protein or fat on the infectious process of SARS-CoV-2 found for populations of five continents was also manifested for nations of 44 countries combined in 14 different regions of these continents. Correlation between infection prevalence and GDP, amount of protein or fat consumption around 14 regions exhibited r = 0.76, r = 0.69, or r = 0.87. These coefficients for IFR were 0.48, 0.45, and 0.63, which were smaller than the related continent rates.

[13] New Food Balances. URL: https://FAO.org/faostat/en/#data/FBS (accessed 20.07.2021).
[14] Worldometer (accessed 31.05.2022).
[15] New Food Balances. URL: https://FAO.org/faostat/en/#data/FBS (accessed 20.07.2021).
[16] Ibid.
[17] Ibid.
[18] Our World in Data (accessed 20.07.2021); World Bank Open Data (accessed 20.07.2021).
[19] New Food Balances. URL: https://FAO.org/faostat/en/#data/FBS (accessed 20.07.2021).

The number of incidents and mortalities from COVID-19 has undulating increased and achieved in 15 months, on 10 June 2021, respectively about 180 and 4 mln[20]. Until June 2021, humanity was not able to reach the global level of anti-COVID vaccination. It achieved less than 50% only in some groups of residents in a few states in Europe and America. Currently, many thousand results of various studies of medical epidemiology on the Coronavirus SARS-CoV-2 and induced disease have been published on the Internet. The risk factors for the infection that caused the pandemic and the technologies to overcome it have been also intensively studied. It is undeniable that timely and reliable isolation from sources of infection prevents an epidemic of any transmissible pathogen, including the virus SARS-CoV-2. The high quality of medical service ensures effective treatment of patients and reduces mortality. The influence of these two practices, as well as vaccination, has been demonstrated in a huge number of studies on pathogen invasion and the dynamic of the infectious disease of the different viruses. These three known activities are essential in a practical strategy model to prevent virus epidemics or pandemics.

Analysis of statistical data on the development of infection SARS-CoV-2 on different continents and their 15 regions showed huge variability in COVID-patient morbidity and mortality (Fig. 2–4). The total number of infected patients and victims of the pandemic in different continents varied significantly and can differ by almost 20 times if we compare these data for NA and Africa (Fig. 1, 2, 4). Until now, no factors have been identified which could explain a significant difference in the deaths from SARS-CoV-2 infection in different regions or continents. Ethnicity or population density with r = -0.16–0.24 were less determining factors than the GDP or diet (r = 0.76 or r = 0.70–0.87) for the development of the COVID-19 epidemic (Fig. 4, Table 4). Figures 2 and 4 present that populations from regions with high income where protein and fat consumption per capita were considerably greater than the WHO recommendation had the highest number of infection cases and the highest death rate from COVID-19 per one million. Asia and Europe have the largest number of total reported infected patients, while NA and South America have the highest number of deaths per one million inhabitants. In America and Europe, people eat more fat and protein than in Asia or Africa. It cannot be ruled out that in some countries in Asia or Africa many undiagnosed cases were not reflected in the statistics [12, 23].

The development of a pandemic not only affects the socioeconomic condition of the population but also depends on it. However, the phenomenon of resistance of populations with a low-protein or low-fat diet against SARS-CoV-2 infection remains to be studied.

Conclusions

This review analyzed the impact of geographic isolation, ethnicity, population density, GDP, and amount of staple food consumption on the development of the epidemic process of SARS-CoV-2 over 15 months in statistical populations representing residents of five continents split into 14 groups from 44 lands and a group of eight island countries. Analysis of big statistical data has shown: low GDP and adequate total protein, or fat intake coincided with appropriate lower rates of Coronavirus SARS-CoV-2 pathogenic outcomes. The development of the epidemic process did not strongly correlate with ethnicity or population density in this investigation.

The factor of nation isolation from spreading infection is primarily preventive, as it avoids contact between the organism and the pathogen. Diets cannot affect the transmission of virions, but after the introduction of a virus into the body, the influence of nutritional components on the destructive biochemical reactions of the pathogen in the host's body is possible.

According to the prediction of WHO experts, this pandemic can persist for at least three years, but it is difficult to forecast the exact end date. Radical methods are needed to fight the pandemic. Here was proposed that overconsuming protein and fat may be a risk factor for COVID-19 pathogenesis. Comparison of statistical data performed on large samples, longer periods, and cohort studies will help to create an optimal model and methods to defeat the COVID-19 pandemic.

References

1. **Liu X.X.** et al. A New SEAIRD Pandemic Prediction Model with Clinical and Epidemiological Data Analysis on COVID-19 Outbreak. *Applied Intelligence*. 2021;51(7):4162–4198. Available from: https://doi.org/10.1007/s10489-020-01938-3.

[20] WHO. Coronavirus Disease (COVID-19) Pandemic (accessed 10.09.2021); Worldometer (accessed 31.05.2022).

2. **Plazas A.** et al. Modeling Partial Lockdowns in Multiplex Networks Using Partition Strategies. *Applied Network Science*. 2021;6(27):1–15. Available from: https://doi.org/10.1007/s41109-021-00366-7.

3. **Zhang W.** et al. Analysis of COVID-19 Epidemic and Clinical Risk Factors of Patients Under Epidemiological Markov Model. *Results in Physics*. 2021;22:103881. Available from: https://doi.org/10.1016/j.rinp.2021.103881 (accessed 20.07.2021).

4. **Hu B.** et al. Characteristics of SARS-CoV-2 and COVID-19. *Nature Reviews Microbiology*. 2021;19:141–154. Available from: https://doi.org/10.1038/s41579-020-00459-7.

5. **V'kovski P.** et al. Coronavirus Biology and Replication: Implications for SARS-CoV-2. *Nature Reviews Microbiology*. 2021;(19):155–170. Available from: https://doi.org/10.1038/s41579-020-00468-6.

6. **Wu S.-C.** et al. The SARS-CoV-2 Receptor-Binding Domain Preferentially Recognizes Blood Group A. *Blood Advances*. 2021;5(5):1305–1309. Available from: https://doi.org/10.1182/bloodadvances.2020003259.

7. **Booth A.** et al. Population Risk Factors for Severe Disease and Mortality in COVID19: A Global Systematic Review and Meta-Analysis. *PLoS ONE*. 2021;16(3):e0247461. Available from: https://doi.org/10.1371/journal.pone.0247461 (accessed 31.05.2022).

8. **Castilla J.** et al. Risk Factors of Infection, Hospitalization and Death from SARS-CoV-2: A Population-Based Cohort Study. *Journal of Clinical Medicine*. 2021;10(12):2608. Available from: https://doi.org/10.3390/jcm10122608.

9. **Mentella M.C.** et al. The Role of Nutrition in the COVID-19 Pandemic. *Nutrients*. 2021;13(4):1093. Available from: https://doi.org/10.3390/nu13041093.

10. **Hashim M.J., Alsuwaidi A.R., Khan G.** Population Risk Factors for COVID-19 Mortality in 93 Countries. *J Epidemiol Glob Health*. 2020;10(3):204–208. Available from: https://doi:10.2991/jegh.k.200721.001.

11. **Kontis V.** et al. Magnitude, Demographics and Dynamics of the Effect of the First Wave of the COVID-19 Pandemic on All-Cause Mortality in 21 Industrialized Countries. *Nature Medicine*. 2020;26:1919–1928. Available from: https://doi.org/10.1038/s41591-020-1112-0.

12. **Wamaia R.G.** et al. What Could Explain the Lower COVID-19 Burden in Africa Despite Considerable Circulation of the SARS-CoV-2 Virus? *International Journal of Environmental Research and Public Health*. 2021;18(16):8638. Available from: https://doi.org/10.3390/ijerph18168638 (accessed 31.05.2022).

13. **Williamson E.J.** et al. Factors Associated with COVID-19-Related Death Using OpenSAFELY. *Nature*. 2020;584:430–436. Available from: https://doi.org/10.1038/s41586-020-2521-4.

14. **Jin J.** et al. Individual and Community-Level Risk for COVID-19 Mortality in the United States. *Nature Medicine*. 2021;27:264–269. Available from: https://doi.org/10.1038/s41591-020-01191-8.

15. **Mathur R.** et al. Ethnic Differences in SARS-CoV-2 Infection and COVID-19-Related Hospitalisation, Intensive Care Unit Admission, and Death in 17 Million Adults in England: An Observational Cohort Study Using the OpenSAFELY Platform. *Lancet*. 2021;397(10286):1711–1724. Available from: https://doi: 10.1016/S0140-6736(21)00634-6.

16. **Roy S., Ghosh P.** Factors Affecting COVID-19 Infected and Death Rates Inform Lockdown-Related Policymaking. *PLoS One*. 2020;15(10):e0241165. Available from: https://doi.org/10.1371/journal.pone.0241165 (accessed 20.07.2021).

17. **Siegel M.** et al. Actual Racial/Ethnic Disparities in COVID-19 Mortality for the Non-Hispanic Black Compared to Non-Hispanic White Population in 35 US States and Their Association with Structural Racism. *Journal of Racial and Ethnic Health Disparities*. 2022;9(3):886–898. Available from: https://doi.org/10.1007/s40615-021-01028-1 (accessed 20.07.2021).

18. **Tan A.X.** et al. Association Between Income Inequality and County-Level COVID-19 Cases and Deaths in the US. *JAMA Netw Open*. 2021;4(5):e218799. Available from: https://doi:10.1001/jamanetworkopen.2021.8799 (accessed 07.08.2021).

19. **Mokhtari T.** et al. COVID-19 and Multiorgan Failure: A Narrative Review on Potential Mechanisms. *J Mol Histol*. 2020;51(6):613-628. Available from: https://doi.org/10.1007/s10735-020-09915-3.

20. **Kordzadeh-Kermani E., Khalili H., Karimzadeh I.** Pathogenesis, Clinical Manifestations and Complications of Coronavirus Disease 2019 (COVID-19). *Future Microbiology*. 2020;15(13):1287 1305. Available from: https://doi.org/10.2217/fmb-2020-0110.

21. **Al-Aly Z., Xie Y., Bowe B.** High-Dimensional Characterization of Post-Acute Sequelae of COVID-19. *Nature*. 2021;594:259–264. Available from: https://doi.org/10.1038/s41586-021-03553-9 (accessed 20.07.2021).

22. **Sudre C.H.** et al. Attributes and Predictors of Long COVID. *Nature Medicine*. 2021;27(4):626–631. Available from: https://doi.org/10.1038/s41591-021-01292-y.

23. **Karlinsky A., Kobak D.** The World Mortality Dataset: Tracking Excess Mortality Across Countries During the COVID-19 Pandemic. Preprint. *medRxiv*. Posted June 04, 2021. Available from: https://doi.org/10.1101/2021.01.27.21250604 (accessed 08.08.2021).

24. FAO of the United Nations, WHO, United Nations University. Protein and Amino Acid Requirements in Human Nutrition: Report of a Joint FAO/WHO/UNU Expert Consultation. *World Health Organization Technical Report Series*. 2007;935:1–265. Available from: https://apps.who.int/iris/handle/10665/43411.

25. **Akhtar S.** et al. Nutritional Perspectives for the Prevention and Mitigation of COVID-19. *Nutrition Reviews*. 2021;79(3):289–300. Available from: https://doi.org/10.1093/nutrit/nuaa063.

26. **Allard L.** et al. Malnutrition: Percentage and Association with Prognosis in Patients Hospitalized for Coronavirus Disease 2019. *Nutrients*. 2020;12(12):3679. Available from: https://doi.org/10.3390/nu12123679.

27. **Hu X.** et al. Predictive Value of the Prognostic Nutritional Index for the Severity of Coronavirus Disease

2019. *Nutrition*. 2021;84:111123. Available from: https://doi.org/10.1016/j.nut.2020.111123 (accessed 20.07.2021).

28. **Rothenberg E.** Coronavirus Disease 19 from the Perspective of Ageing with Focus on Nutritional Status and Nutrition Management – A Narrative Review. *Nutrients*. 2021;13(4):1294. Available from: https://doi.org/10.3390/nu13041294.

29. **Sahin E.** et al. Clinical Impact Potential of Supplemental Nutrients as Adjuncts of Therapy in High-Risk COVID-19 for Obese Patients. *Frontiers in Nutrition*. 2020;7:580504. Available from: https://doi.org/10.3389/fnut.2020.580504 (accessed 20.07.2021).

30. **Bedock D.** et al. Evolution of Nutritional Status after Early Nutritional Management in COVID-19 Hospitalized Patients. *Nutrients*. 2021;13(7):2276. Available from: https://doi.org/10.3390/nu13072276.

31. **Bousquet J.** et al. Is Diet Partly Responsible for Differences in COVID-19 Death Rates Between and Within Countries? *Clinical and Translational Allergy*. 2020;10:16. Available from: https:// doi.org/10.1186/s13601-020-00323-0.

32. **Clemente-Suárez V.J.** et al. Nutrition in the Actual COVID-19 Pandemic. A Narrative Review. *Nutrients*. 2021;13(6):1924. Available from: https://doi.org/10.3390/nu13061924.

33. **Greene M.W., Roberts A.P., Frugé A.D.** Negative Association Between Mediterranean Diet Adherence and COVID-19 Cases and Related Deaths in Spain and 23 OECD Countries: An Ecological Study. *Frontiers in Nutrition*. 2021;8:591964. Available from: https://doi.org/10.3389/fnut.2021.591964 (accessed 20.07.2021).

34. **James P.T.** et al. The Role of Nutrition in COVID-19 Susceptibility and Severity of Disease: A Systematic Review. *The Journal of Nutrition*. 2021;151(7):1854–1878. Available from: https://doi.org/10.1093/jn/nxab059 (accessed 20.08.2021).

35. **Mechanick J.I.** et al. Clinical Nutrition Research and the COVID-19 Pandemic: A Scoping Review of the ASPEN COVID-19 Task Force on Nutrition Research. *Journal of Parenteral and Enteral Nutrition*. 2021;45(1):13–31. Available from: https://doi.org/10.1002/jpen.2036.

36. **Mortaz E.** et al. Nutritional Impact and Its Potential Consequences on COVID-19 Severity. *Frontiers in Nutrition*. 2021;8:698617. Available from: https://doi.org/10.3389/fnut.2021.698617 (accessed 31.05.2022).

37. **Perez-Araluce R.** et al. Mediterranean Diet and the Risk of COVID-19 in the 'Seguimiento Universidad de Navarra' Cohort. *Clinical Nutrition*. 2022;41(12):3061–3068. Available from: https://doi.org/10.1016/j.clnu.2021.04.001 (accessed 20.07.2022).

About the author

Sophia V. Ponomarenko – Dr. rer. nat., Project Manager, SophiGen inGr. 42, Siemensstraße, Bönen, 59199, Germany. E-mail: sp@sophigen.com. ORCID: https://orcid.org/0000-0003-2141-5494.

Информация об авторе

Пономаренко София Васильевна – канд. биол. наук, руководитель проекта, ООО «SophiGen inGr». 59199, г. Бёнен, Сименсштрассе, д. 42, Германия. E-mail: sp@sophigen.com. ORCID: https://orcid.org/0000-0003-2141-5494.